Combating Consumer Food Waste – An Exploration of Information Communication Technology Approach

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Abstract: Existing food production and consumption rate, especially from consumer's point of view, cannot be measured as viable due to varieties of social economic factors involved in the food supply chain. Combating food waste contributes extensively to food security measures and easing conservational burden thus improving justifiable consumption of food. Food waste emanating from consumers especially individual households is huge. A systematic approach to mitigate this is creatively enlightening consumers through alertness and campaigns. However, literature reveals that complimentary initiatives are required to confront the problem of consumer waste. Emerging technologies and their uniqueness are comparatively gaining attention to lead consumers carefully using improved technical platforms and solutions in the right direction towards reducing food waste. This study tackles this research gap by conducting comprehensive reviews of articles pointing to food wastage prevention, weaknesses, and potential usage of ICT tools to positively impact consumers and reduce food wastage. The study focuses on the use of ICT tools and techniques as a means to reduce food wastage. The reviews covered existing food wastage-saving measures and applications (e.g., smart kitchen appliances, smart packaging and mobile applications). It further proposed a broad ICT driven food wastage avoidance framework that deals with the problem holistically. The framework shows how various levels of the food supply chain can be integrated to tackle wastages from top to bottom in avoiding consumer wastage. However, future research is required to validate and build on this framework.

Keywords: *food waste; food production; Information technology; supply chain, smart systems*

1.0 Introduction

Food waste has been recognized as a major global problem impacting the economy, the environment, and food security. Food and Agriculture Organization (FAO) estimates that roughly 1.3 billion tons of food are lost or wasted annually, or about one-third of all food produced worldwide [1], [2]. The complete food supply system, from production to consumption, is affected by this waste. Most food waste in developed nations happens during consumption, with households and food service businesses being the primary offenders. Contrarily, in developing nations, most food waste occurs during the manufacturing and post-harvest phases [3]. Food waste has serious and wide-ranging effects. First, it adds to global greenhouse gas emissions, with about 6% of all greenhouse gas emissions coming from food waste. [4]. Second, it results in the inefficient use of resources necessary for food production, such as water and territory. Third, food waste worsens food insecurity, with an estimated 828 million people going hungry worldwide [5]. Also, food waste places a heavy financial load on the world economy, costing it $940 billion annually [6]. Given the significant negative effects of food waste, it is essential to avoid and manage food waste effectively. Preventing and managing food loss can lower greenhouse gas emissions, protect natural resources, ease food insecurity, and have a positive economic impact. The accomplishment of several

Sustainable Development Goals (SDGs), including SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 13, can be facilitated through effective methods for preventing and managing food waste [7], [8]. A potential remedy for the problem of food waste has been identified in the form of information and communication technology (ICT) tools [9].

The term "ICT tools" refers to various digital platforms and technologies that can aid communication, data gathering, and analysis[10-12]. By facilitating food donation and redistribution, enhancing food inventory management, and encouraging customer behavior change, these tools can aid in managing and preventing food waste. Several ICT tools, such as mobile apps [13], cloud-based platforms [14], and sensor technologies [15], have been created to address food waste. For instance, smartphone apps like Too Good To Go and OLIO enable customers to buy leftover food from nearby restaurants and grocery stores at a discount [16], [17]. To enable food donation and redistribution, cloud-based systems like FoodCloud link food donors with regional charities and food banks [18]. By providing real-time data on food waste generation, sensor technologies, such as those created by Winnow Solutions and Leanpath, assist food service businesses in monitoring and reducing food waste [19]. This review aims to examine how Information Communication Technology (ICT) tools can be used to avoid and manage consumer food waste. An overview of the present state of study on ICT tools for managing and preventing food waste, including their efficacy, drawbacks, and potential for expansion, will be provided in the review. The review will also point out gaps in the body of knowledge and recommend places for further investigation. This review seeks to shed light on the function of ICT tools in addressing the problem of food waste and encouraging sustainable consumption and production patterns by synthesizing the available literature.

2.0 Role of Consumers in Reducing Food Waste

Consumers are a major cause of food waste. According to studies, households account for more than 50% of food waste worldwide [20]. This issue is exacerbated by consumer behaviors like over-purchasing, inadequate storing, and disregarding food approaching its expiration date [21]. Therefore, to decrease food waste, it is essential to concentrate on consumer behavior. Proper planning of meals is one method to lessen food waste. Meal planning has been shown in WRAP's (Waste & Resources Action Programme) research to reduce household food waste [22]. Additionally, consumers can give food to food banks, compost food scraps, and repurpose leftovers for new meals [23]. Meanwhile, various social-economic factors in the food supply chain contribute to wastage [24]. These factors begin with consumer's attitude, especially at homes or restaurants where applicable; individual beliefs, behaviour, and attitudes are also considered. For illustrative purposes; in some parts of the world, certain consumers do not eat a chicken's head/feet; in other parts, the feet of a chicken are a complete meal. In other words, in area where this is not been consumed, it could be regarded as food wastage. Other social cultural factors include but not limited to shopping routines, nature of packaging and kinds of food being purchased per time.

However, consumers might not be conscious of these options and might not prioritize reducing food waste. ICT resources can be very helpful in educating and motivating customers to act in this situation. ICT tools, such as mobile apps, have been created to encourage consumer behavior change and decrease food waste. These resources offer advice on proper food storage, portion management, and strategies for reducing food waste. For instance, the smartphone application "Too Good to Go" links customers with nearby restaurants and grocery shops to buy food that would otherwise go to waste [25]. The "Love Food Hate Waste" and "NoWaste" applications are two additional instances of ICT tools designed to decrease consumer food waste [26], [27]. Overall, educating and

encouraging consumers to reduce food waste is essential. ICT tools can play a vital role by providing information and promoting behavior change.

3.0 Collaboration of Stakeholders in Food Waste Prevention and Management

Collaboration between stakeholders is essential for successful food waste control and prevention. To minimize food waste and increase its worth, various players in the food supply chain, such as farmers, food manufacturers, retailers, and consumers, must be involved [28]. Initiatives to avoid and manage food waste rely heavily on the degree of cooperation and coordination among stakeholders. In recent years, there has been an increasing understanding of the value of stakeholder cooperation in reducing food waste. Governments, non-profit organizations, and private businesses have started numerous initiatives to encourage cooperation and facilitate information sharing among stakeholders. For instance, the United Kingdom's Food Waste Reduction Roadmap, unveiled in 2018, is a joint effort between the government, retailers, and food producers to decrease food waste by 20% by 2025 [29].

Partnerships between various participants in the food supply chain are another type of collaboration. For instance, by enhancing inventory control, packaging design, and distribution procedures, food producers and merchants can collaborate to streamline the supply chain and cut waste [30]. Another illustration is the collaboration between supermarkets and charities, where extra food is given to organizations that serve the hungry [31]. ICT tools can significantly aid in fostering stakeholder cooperation by offering a forum for information exchange and communication. For instance, the FUSIONS project, which received funding from the EU, created an online platform that enables stakeholders to exchange information and best practices for managing and preventing food waste [32]. Another illustration is the FoodCloud network, which links merchants and charities to make donating surplus food easier [18].

Based on the aforementioned, stakeholder collaboration is crucial in reducing food waste and maximizing its value. ICT tools facilitate collaboration by providing a platform for information sharing and communication. Through collaboration, stakeholders can identify and implement effective solutions for preventing and managing food waste.

4.0 Overview of ICT Tools and Services for Food Waste Management

ICT tools and services have shown great potential in food waste management by supporting consumers and other stakeholders in making informed decisions to prevent and reduce food waste. This section provides an overview of three main categories of ICT tools and services for food waste management: mobile applications, smart kitchen appliances, and smart packaging.

4.1 Mobile Applications

Consumers now frequently use mobile applications and related services, also referred to as apps, to control their food waste. These applications offer functions such as meal planning, inventory monitoring, and reminders for expiration dates. Too Good to Go, Olio, and NoWaste are well-known food waste control applications with various services embedded to combat food waste. Through Too Good to Go, customers can get discounted access to eatery and grocery store surplus food. Conversely, OLIO allows customers to share leftover food with their neighbors. Finally, NoWaste offers recipes using leftover ingredients and assists customers in keeping track of their food inventory and expiration dates. By providing consumers with relevant information and resources, these tools

can increase awareness, facilitate behavior change, and promote collaboration among stakeholders in the food supply chain. For instance, the Too Good To Go app (Table 1.) allows users to purchase surplus food from restaurants and supermarkets at discounted prices, reducing food waste generated in these outlets ([33]. Similarly, the Love Food Hate Waste campaign offers online resources, such as recipes and meal planning tools, to support consumers in managing their food waste [29]. Using mobile applications to manage food waste has several advantages, including lowering food waste, raising awareness, and saving money. Consumers have reported that using food waste management apps can reduce household food waste by up to 50% [34].

Table 1: Description of a surplus food purchasing applications

ICT Tools and Services	Information Provided
Too Good To Go app	Allows users to buy surplus food from local restaurants and shops at a reduced price [25].
OLIO app	Connects users with surplus food from local households and retailers, reducing food waste
Love Food Hate Waste	Provides information on how to reduce food waste at home, including recipes and meal plans
Waste Less, Save More	Provides tips for reducing food waste and tracks the user's progress toward waste reduction
FoodKeeper app	Provides information on food storage, including recommended storage times and optimal storage conditions
Spoiler Alert	Connects food businesses with surplus food to food banks and charities

4.2 Smart Kitchen Appliances

Internet-connected, smart kitchen appliances can aid in the control and prevention of food waste. Smart ovens, freezers, and scales are a few of these products. For instance, Samsung has created a smart refrigerator that keeps track of food inventory and expiration dates and can even recommend recipes based on the materials on hand. Another example is the Drop smart scale, which can adjust a recipe based on the ingredients on hand and recommend recipes based on the weight of the ingredients. Increasing food preparation efficiency, reducing food waste, and saving money are all advantages of smart kitchen tools. For example, it has been reported that smart refrigerators decreased household food waste by up to 20% [35].

4.3 Smart Packaging

The term "smart packaging" refers to intelligent packing that can reduce food waste by conveying details about the product's freshness and quality. The technical flow of a typical smart packaging process is illustrated in Figure 1. Sensors or other signs in smart packaging can detect changes in temperature, humidity, or gas composition. For instance, the Time Temperature Indicator (TTI), which changes hue according to temperature and time, can give a clue as to the quality and freshness of a food product. Increased food quality and freshness transparency, decreased food waste, and possible cost savings are all advantages of smart packaging. According to research, the use of TTI reduced food wastage [36].
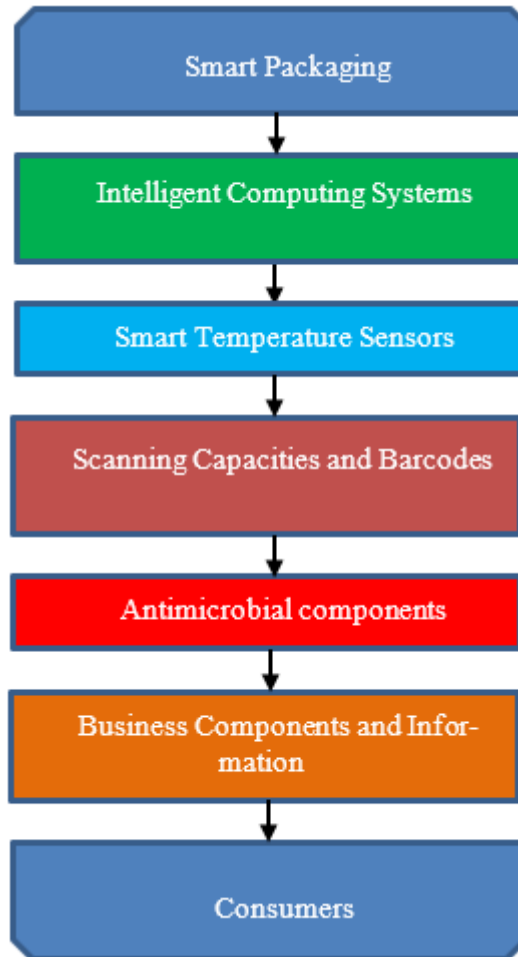
Figure 1: The technical flow of a typical smart packaging System

5.0 Limitations of current ICT tools and Services used in food waste reduction

Despite the ICT tools' promise to manage and prevent food waste, some issues still need to be resolved. The lack of user engagement by ICT professionals to drive adoption of available tools and services is one of the major margins. Despite the abundance of ICT tools at their disposal, not all consumers are conscious of them, and even those who are may not regularly use them. Thus, user involvement and adoption are key factors in determining whether these tools are successful. Studies have shown that when consumers believe ICT tools are simple to use, helpful, and reliable, they are more apt to use them for managing food waste [35]. Therefore, developers must create engaging software and hardware solutions that are user-friendly to the extent of satisfying user requirements.

Another area for improvement of current ICT tools is the need for integration and interoperability. Many ICT tools for food waste management operate in silos, meaning they are not connected to other tools or platforms. This can limit their effectiveness in providing holistic food waste prevention and management solutions.

Interoperability among ICT tools would allow for seamless data sharing and stakeholder collaboration. This will allow portable flow of information usage from one system to another. Furthermore, the reliability and precision of ICT tools' data are other limitations. For instance, apps that track food waste depend on user input, which can sometimes be biased or subject to human error. More effective strategies and methods for managing food waste can result from accurate data. The implementation of efficient data validation methods and quality control measures by developers is necessary to increase the accuracy and reliability of data.

The lack of standardization and regulation is a limitation for the development and deployment of ICT tools and also affects the effectiveness of ICT tools in curbing food waste. Currently, there are no standard guidelines or regulations for developing and deploying food waste management ICT tools. This lack of standardization and regulation can lead to confusion among consumers and stakeholders and hinder the widespread adoption of these tools. Therefore, policymakers and regulatory bodies need to establish guidelines and standards to ensure the quality and effectiveness of ICT tools for food waste prevention and management. Addressing these limitations will improve the effectiveness and uptake of ICT tools for food waste prevention and management, ultimately contributing to a more sustainable and environmentally friendly food system.

5.1 Proposed Framework and Suggestions for future developments

Future developments should prioritize enhancing accessibility, customizability, and effectiveness to resolve the shortcomings of current ICT tools. For instance, efforts should be made to guarantee that ICT tools are accessible to a wider variety of consumers, including those with lower levels of digital literacy. ICT tools should also be customized to particular cultural and regional eating habits to ensure they are applicable and helpful in various settings. Additionally, rather than merely managing the waste after it has been produced, future developments should address the underlying causes of food waste, such as overproduction and oversupply. This may entail using predictive analytics to assist food producers and retailers forecast demand and modify their supply accordingly. Finally, future developments should improve consumers' input accuracy and consistency to ensure that ICT tools effectively reduce food waste. This could involve using sensors and other technologies to automate data collection and reduce the burden on consumers. This work further provides a proposed framework to tackle some of the identified limitations of food waste management and the existing ICT tools deployment through mobile applications. The framework proposed in Figure 2 is all-inclusive.
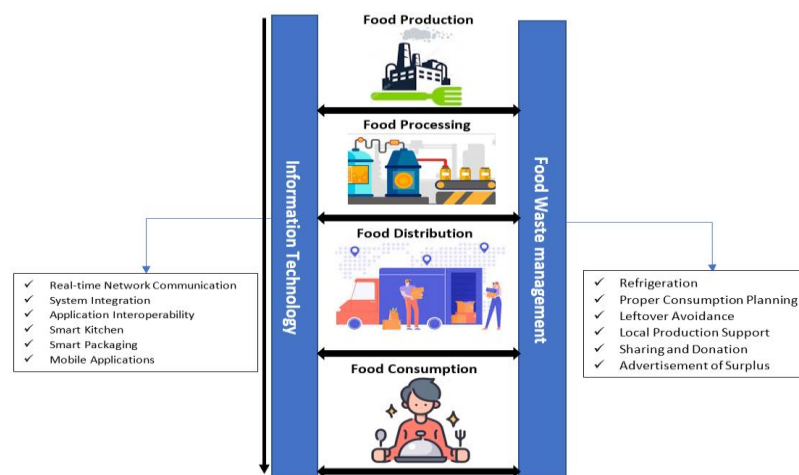

Figure 2: Proposed Framework for Food Waste Management

The encompassing nature of this framework considers the holistic food supply chain from production, processing, distribution, and consumption. Unlike previous approaches which applications are limited to distribution and consumption. The proposed framework tends to fill in the consumption gap from the source. Smart ICT functionalities such as real-time network communication, smart kitchen, and smart packaging are well integrated into the framework in figure 2. This refers to an augmented kitchen and packaging process with smart incorporations of different sensors for effective temperature monitoring. The smart nature of this aspect of the framework will help improve the shelf life of foods, display real-time information related to freshness and quality, and convenience of consumption. Intelligent and smart kitchen appliances are gradually covering the usage of domestic food preparation devices (such as ovens, dishwashers, coffee makers, refrigerators etc). Emerging technologies are enhancing their functionalities for remote monitoring by receiving frequent notifications/alerts about potential damage of food. Kitchen appliances can be controlled with smartphones and other internet-connected gadgets. The framework is flexible and expandable to capture other smart ICT areas such as Big Data, Cloud computing, Internet of Things (IoT). IoT is an integral part of Home [37] and this is the situation for taking advantage of network communication functionalities to reduce food waste as quick as possible even when not physically present in the food location. Other digital technologies that tend to speedily identify issues associated with food waste and mitigate it can be easily deployed using advance communication technologies.

The framework proposed in this study further identified various food waste management measures with integrated information communication technologies such as real time network communication systems, smart and mobile systems, and several other ICT techniques that can facilitate stakeholder's collaboration in combating food wastage.

6.0 Conclusion

Overall, the efficacy of ICT tools for food waste prevention and management will rely on their capacity to address the underlying causes of food waste and their accessibility, adaptability, and effectiveness for various settings and consumer groups at all levels. A crucial component of sustainable food production and consumption is preventing and controlling food waste through the supply chain process. Food waste has major negative effects on the environment, the economy, and society, requiring immediate attention. A potential answer to successfully address the problem of food waste is the introduction of ICT tools. The proposed framework in this study ad its review emphasizes how ICT tools can support consumers, promote stakeholder cooperation and lessen food waste. Numerous studies have demonstrated the efficiency of ICT tools in decreasing food waste, and the advantages are numerous.

ICT tools today do, however, still have some drawbacks, such as poor adoption rates, little awareness, and accessibility issues. Future research is necessary to overcome these obstacles and unlock the full potential of ICT tools by implementing the proposed framework. ICT tools must be adopted by all parties involved in the food industry, including consumers, retailers, manufacturers, and policymakers, to produce and utilize food sustainably as indicated in the output of this findings (proposed framework). The potential benefits are significant, and the call to action is clear: work together to prevent and manage food waste effectively using innovative and technology-driven solutions, as illustrated in the proposed framework. This will improve the current ICT tools and its need for integration and interoperability Doing so can lead to a more sustainable food system and a better future in combating food wastage not only at the consumer level but at every stage of the supply chain.

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Authors contribution

John Adebisi: *Preliminary studies, framework design, results interpretation, and report writing.,* Khadeejah A. Abdulsalam: *Literature review, report writing and editing,* Michael Emezirinwune: *data gathering and report writing*, Ndjuluwa N.P. Leokadia: *Problem formulation, result analysis, and report writing.*

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